FORECASTING TORNADOES IN GEORGIA

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ABSTRACT

Some climatological data on the seasonal, diurnal, and geographical distribution of tornadoes in Georgia are presented, and the tornado "season" is defined as occurring from February through April. Twelve different storms producing tornadoes during one or more 12-hour forecast periods are studied for synoptic similarities. A mean tornado sounding and a 700-mb. composite chart, taken from data preceding tornado occurrences, are shown. Large differences are found in surface map types whereas at the 700-mb. level there are striking similarities. The synoptic similarities are incorporated into an objective forecast aid through a stratification process such that most "no-tornado" cases are quickly dismissed by an inspection of the maps currently available in forecast offices, whereas "threat" cases must be further checked against five criteria and four scatter diagrams. Tests show that this aid, when used as a method in itself, correctly anticipates most of these storms and at the same time, it results in about 2½ forecasts of tornadoes for every one reported.

INTRODUCTION

The tornado is the most violent and destructive, per unit area, of all weather phenomena in the United States with which the forecaster must deal. These storms occur rather infrequently and when they do occur they are so localized that the forecasting problems involved have seemed almost insurmountable to many forecasters. However, the concentrated efforts of several investigators during recent years have produced such encouraging results that forecasts of these storms over limited areas and for relatively short lengths of time are now believed to be warranted. While the frequency of tornadoes in Georgia is relatively small as compared with many States, their occasional occurrence still poses a serious problem to the forecaster in this area. Indeed, the infrequency of occurrence of these destructive storms tends to accentuate the seriousness of this problem rather than to detract from it. Three tornadoes have claimed some 328 lives and one of the most destructive tornadoes ever reported struck Gainesville on April 6, 1936, taking 203 lives.

Most investigators have been largely concerned with the tornado problem in those areas where they are more often observed. For one thing, much more data on occurrences are available for study and also the greater destruction to life and property demands the attention of those few who are able to study this problem. During the spring season of 1952, the forecasters at the Weather Bureau District Forecast Office in Atlanta closely followed the forecast technique which was devised by Fawbush, Miller, and Starrett [1]. In addition, close attention was also given to ideas on squall line formation and tornado development which have been presented by Lloyd [2], Showalter and Fulks [3], Crawford [4], and Fulks [5]. This study was necessarily limited but there seemed to be some evidence that the development of tornadoes in Georgia resulted from somewhat different causes than those which have been studied farther west and for which forecast rules have been formulated.

Climatological data furnished by the Climatological

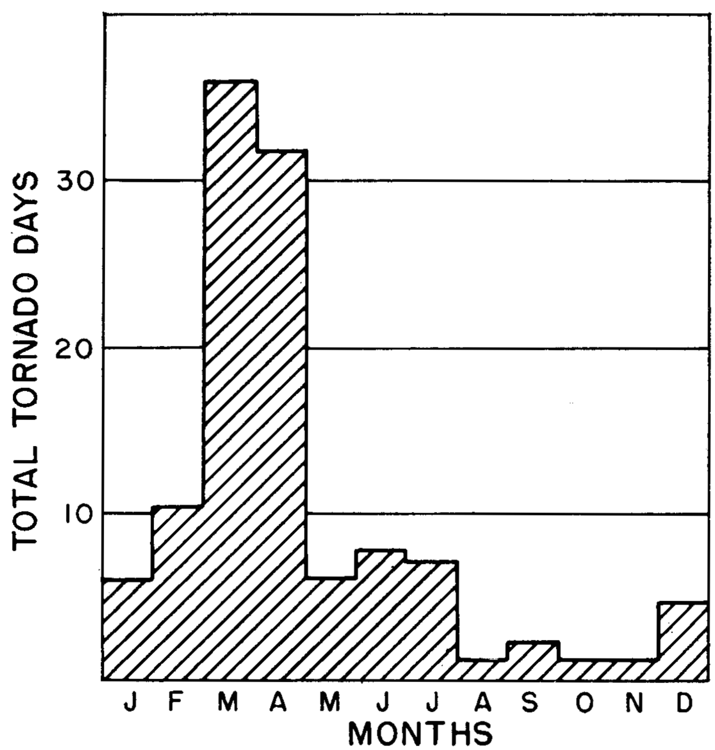

FIGURE 1.—Diagram showing the monthly variation in tornado days for Georgia, 1880–1942.

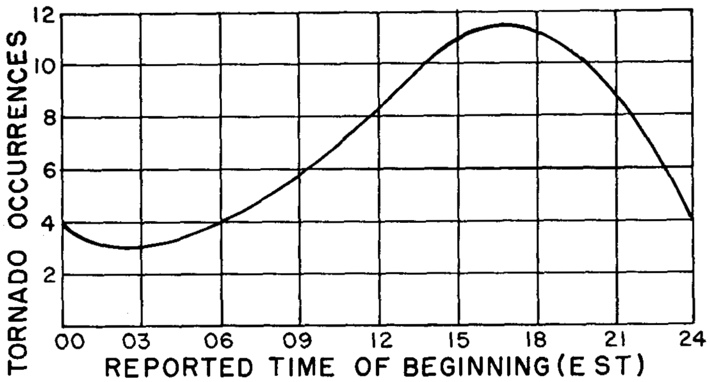

Figure 2.—Diagram showing the hourly frequency distribution (smoothed) of reported tornadoes in Georgia, 1916–50.

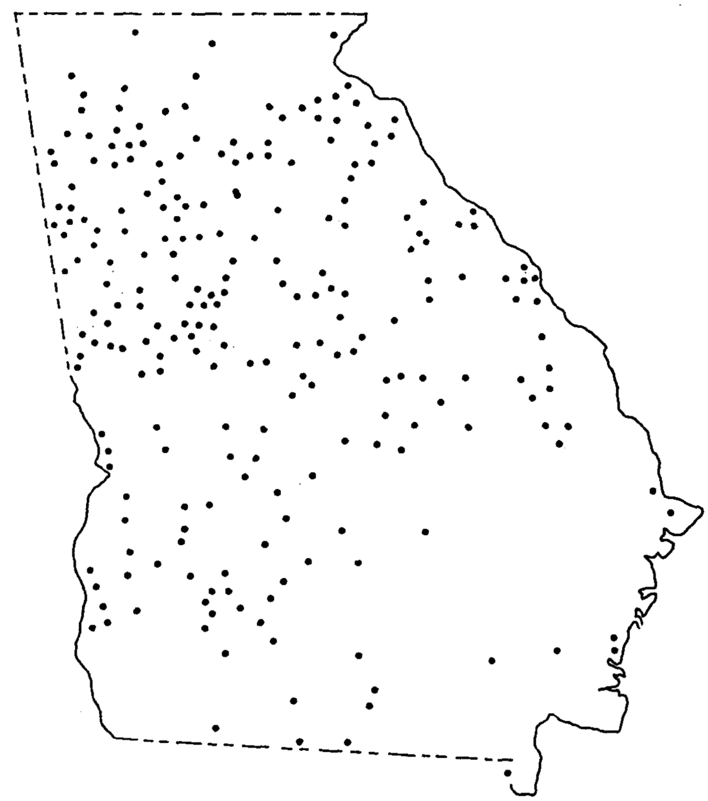

Figure 3.—Map showing the locations of all reported tornadoes in Georgia from 1884 through May 1952.

Division of the U. S. Weather Bureau and based on 62 years of record on the monthly frequency distribution, shown in figure 1, clearly outlines the tornado "season" in Georgia as occurring during the months of February, March, and April. The diurnal frequency distribution was taken from these data also, but only for the years 1914–40; a smooth curve of these data is shown in figure 2. While this curve shows a maximum around 1700 EST, the diurnal variation in frequency is decidedly less than in those areas where tornadoes occur more frequently—Kansas, for example. It was therefore decided to disregard any diurnal effects and limit the study of tornadoes in Georgia to the months of February, March, and April, plus January since the climatology would be similar to February and March.

Mindling [6] has pointed out that there is a "Tornado belt" about 60 miles wide that is parallel to and slightly south of the Appalachian Mountains. The reported tornadoes during the past 68 years are shown in figure 3 and while the locations of storms reported during the past 14 years plus those shown in Mindling's paper do not completely verify his statement, there appears to be a concentration in this area. However, these data are not entirely representative because the areas over which the fewest tornadoes have been reported are, in some cases, coincident with the sparsely populated areas. Very few tornadoes have ever been reported in the vicinity of the Okefenokee swamp in southeast Georgia whereas the greatest concentration of occurrences is within an 80-mile radius of Atlanta. On the other hand, the areas over eastern Georgia between Savannah and Augusta, extreme northwest Georgia, and extreme southwest Georgia are rather densely populated but relatively few tornadoes have been reported there. These data suggest that most of the apparent concentration is real so that the probability of tornado occurrences over extreme northwest Georgia and over southeast Georgia is considerably less than over the area around Atlanta as shown by Mindling.

Some information regarding the movement of tornadoes or tornado areas from State to State would be desirable because, ordinarily, the period during which the forecaster is most concerned about severe storm warnings for Georgia is that following reports of tornadoes to the west. Some data were compiled on reported tornadoes in Mississippi, Arkansas, and Georgia from January 1934 through April 1952. During this 19-year period, 44 tornado days occurred in Arkansas and, during the following 24-hour period, three tornado days were subsequently reported in Georgia. Forty-four tornado days occurred in Georgia during this same period. A similar check was made of the tornado days in Mississippi and it was found that 42 tornado days occurred there and in 3 cases, tornadoes were subsequently reported in Georgia. It is of some interest to note that in two of these cases, tornado areas appeared to move from Arkansas through Mississippi and on into Georgia. It was found that there were 12 cases (out of 44) in which tornado areas appeared to move from Arkansas to Mississippi. But, in general, the relationship here between tornado days in either Mississippi or Arkansas and Georgia is not a good one so that extrapolation techniques would usually be misleading

The objective of this study was, simply, to learn more about tornado forecasting in Georgia. While this is quite a broad and loosely defined objective, our rather meager knowledge of these phenomena in this area seemed to demand such an approach for the present. There are numerous factors which evidently preclude the achievement of perfect forecasts at this time and this study is aimed at deriving the maximum information with the knowledge, data, and time available for this work. It is not within the scope of this study to thoroughly examine and utilize theoretical considerations regarding tornado development except as they may suggest useful measurements from the various charts which are available or could be provided to the forecaster.

The period of study covered the months of January, February, March, and April of those years for which constant pressure maps are available, 1946 through 1952. Data on reported tornadoes were taken from the records in the Weather Bureau Section Center in Atlanta. Meteorological data on tornado situations were determined at least 8 hours prior to, but no more than 20 hours before the occurrence. This period of record includes only 12 tornado situations and in 4 of these, several tornadoes were reported in consecutive forecast periods. No part of these data was withheld for test purposes. Forecast data chosen from the 0300 GMT soundings and the corresponding 0630 GMT surface data are used to cover the 12-hour forecast period beginning at 0600 EST. Forecast data from the 1500 GMT soundings and the 1830 GMT surface data cover the 12-hour forecast period which begins at 1800 EST.

The investigation was divided into two parts. The first was a study of synoptic types or features of the surface maps, soundings, and some of the upper air charts which preceded tornado occurrences by 8 to 20 hours. In the second phase, these results were utilized through specific definitions and measurements and combined into an objective forecast aid.

SURFACE MAPS

A survey of the surface maps nearest the time of tornado occurrence revealed a wide variety of map types. Of the 12 tornado cases, or tornado days, which occurred during these 7 years, 7 cases could be associated with instability lines, 3 occurred with a cold frontal passage, 1 developed above a warm frontal surface, and the other case occurred in the vicinity of a stationary front. The low pressure centers associated with these fronts ranged from deep, intense storms in Iowa, Illinois, and Indiana, to weak and indefinite centers in the Gulf of Mexico. Even the synoptic situation in the 6 cases of tornadoes with instability lines showed wide difference from map to map. Considering all cases, most of these low centers associated with tornado days were deepening at the time of occurrence but surface indications beforehand were inconclusive.

There were two features of these surface maps that seemed to be common to all 12 situations. The first was the presence of maritime tropical air at the surface where tornadoes were reported (mT air is defined here as having a dew point of 60° F. or higher from January through March and 63° F. in April). The narrow band of high dew points, noted by Fawbush and Miller in more westerly areas, was not observed here. Instead, mT air was rather uniformly distributed over most of the Southeast in these cases. The second feature that was common to all of the surface maps was the absence of a large cold High either over the Midwest or following behind a cold front. Instead, cP or mP air was found, ordinarily just behind a cold front, and no case was found in which Arctic air was replacing mT air over the Southeast.

TORNADO SOUNDINGS

Upper air soundings immediately preceding each of these 12 cases were carefully examined for features that might be common to all, or most of them. The soundings were chosen from Atlanta or Apalachicola, Fla., whichever was closer to the subsequent tornado occurrence and also within the tropical air mass. In 6 of these 12 cases, rain was occurring at the time of the sounding. Nearly continuous rain preceded one tornado case by about 36 hours and 7 tornadoes (the greatest number reported in any storm used in this study) were reported about 50 miles south of Atlanta. Only three of these soundings exhibited the characteristic inversion, with a sharp decrease in moisture above, as suggested by Showalter and Fulks [3] and by Fawbush and Miller [7]. The heights of the base of the inversion in these cases were 6,000, 7,000, and 9,000 feet and all were instability line cases. Six of the ten soundings preceding instability line or cold front cases, including the three above, showed at least small inversions, isothermal layers, or a change in stability along with a layer of dry air with the base of the stable layer ranging from 10,000 to 14,000 feet. The other four soundings showed a smooth lapse rate which about paralleled the moist adiabat and with very high moisture values throughout. The sounding for the warm front case showed a typical moist inversion at 10,000 feet and very dry air above 500 mb. The sounding for the stationary front case was relatively moist throughout and although it was rather stable there were neither inversions nor isothermal layers.

A mean sounding for these 12 cases was constructed by averaging temperature and dew point values at each 50-mb. level from 950 to 400 mb., plus the 980-mb. level. This technique would tend to smooth out inversions or isothermal layers, so the average height of the base and top of the inversion, the average temperature increase through the inversion, and average dew point values were determined for six cases. These averages are shown as dotted lines in figure 4 along with the mean sounding. The Showalter Stability Index [8] in these 12 cases ranged from +9 to −3 with an average of about +3°. This analysis of tornado soundings taken within 50 to 200 miles of the tornado occurrence and from 5 to 12 hours before, revealed quite a wide variety of soundings and evidently the only important feature that they all had in common was rather high moisture values at the 850-mb. level and below. It was noted that a decrease of equivalent potential temperature with height is also a common feature of these soundings, but since it is a normal characteristic of mT air in this area, it is not considered to be of any importance or forecast value here.

850-MB. CHARTS

Some study of the individual 850-mb. charts prior to tornado development showed that most of these maps exhibited a pattern similar to that found by Crawford [4] as being necessary for instability line development. Warm air, usually 10° C. or higher, was already over Georgia and estimated dew points at the time and place of tornado occurrence were at least 8° C. or higher. Also, there was usually very cold air west of a trough located near the Mississippi River. However, there was considerable variation in map types so that the only important feature of these charts that appeared to be common to all of these cases was very moist air immediately upstream from tornado occurrence.

700-MB. CHARTS

A composite 700-mb. chart, figure 5, was prepared for all of these tornado cases and since four of them occurred in consecutive forecast periods, as defined here, these data are based upon 16 different maps. This chart shows a pronounced trough over the Plains States with warm air ahead and cold air behind the trough line. Further study of the individual cases revealed that all of these troughs (closed Lows in 10 cases) had cold air behind and

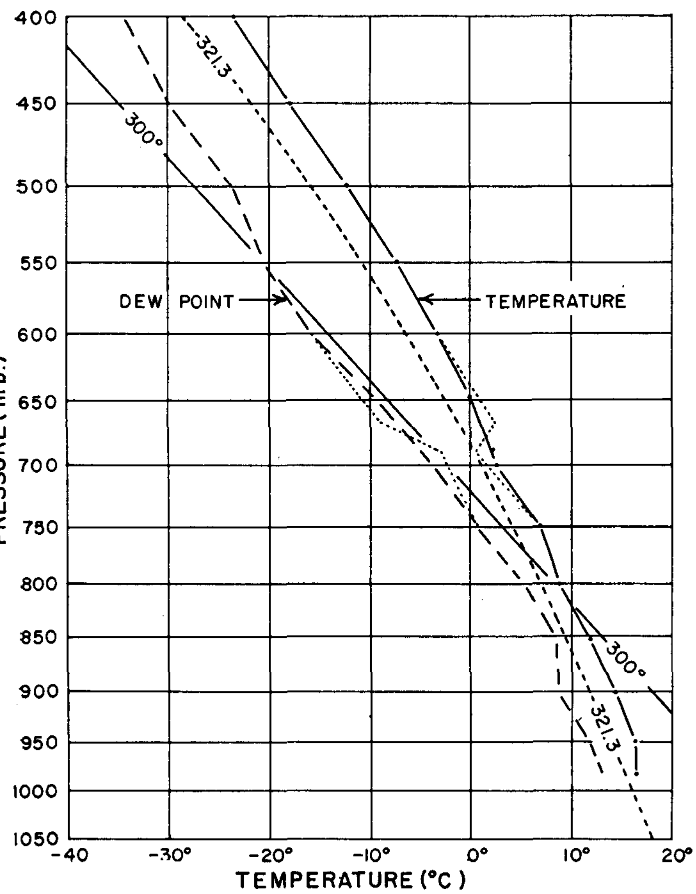

FIGURE 4.—Mean sounding of 12 tornado cases in Georgia. The solid line is the temperature curve, the dashed line is the dew point curve, and the dotted lines represent a mean of 6 cases which had inversions or isothermal layers.

pronounced warm air ahead of the trough line. This is nearly identical to the pattern that Crawford [4] found necessary for instability line development and also, in most cases, very similar to George's Cyclogenesis Pattern [9]. This temperature distribution seems to be a very important factor since tornadoes were never observed with cold air over Atlanta or warm air over the southern Plains. Also, if temperatures are colder over southern California than just behind the cold trough in the Plains, tornado situations evidently do not develop in Georgia. Another feature of these charts that was common to all was a belt of very strong westerly to southwesterly winds, and/or unusually strong contour gradient just ahead of the trough line over the Southern States, usually Texas or Louisiana. This feature is similar to a rule proposed by Fawbush, Miller, and Starrett [1] for tornado occurrence farther west. In all cases the trough was well west of Georgia between Amarillo and Memphis, so that the winds over Georgia were from the west to southwest and never from the south. The flow was always cyclonic or tending toward cyclonic and no tornado cases were found in which unquestionable anticyclonic flow prevailed over Georgia during the 12 hours prior to tornado occurrence.

Some further study of these 700-mb. charts showed that most of the tornado situations were associated with fast-moving troughs which were frequently deepening and never filling or flattening. In these cases, the cold tongue was within 200–300 miles of the trough line. Some further study, necessarily limited, of numerous cases of pronounced 700-mb. troughs which included many "no-tornado" situations suggested a relation between trough speed of movement and the distance of the cold tongue behind the trough line. With the cold tongue located from 200–300 miles behind the trough line, the trough moved rather rapidly; a distance of 400–600 miles between the trough and cold tongue was marked by slower movement than normal; but where the distance increased to 600–1,000 miles, the trough either remained stationary or

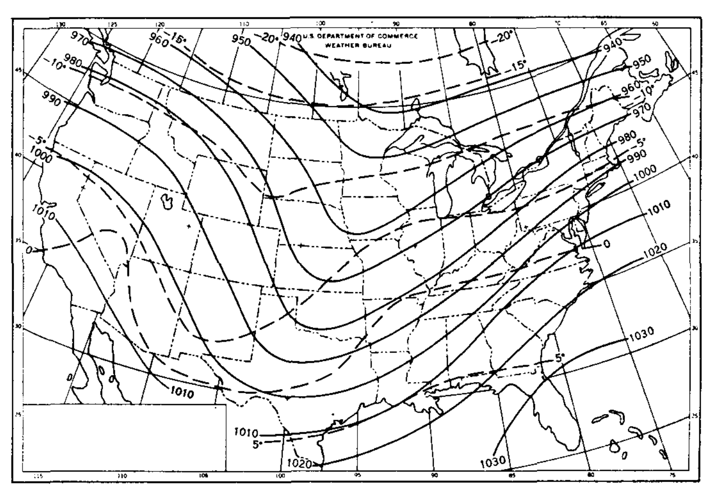

FIGURE 5.—Composite chart of 700-mb. data which preceded the occurrence of 16 tornado periods in Georgia from 1946 through 1952. The solid lines are contours and the dashed lines are isotherms.

developed retrograde movement. This is in general agreement with a previous study of trough movements at this level [10]. Thus the 700-mb. trough must be a moving one but no attempt was made to define the speed of movement through the isotherm-contour relationship.

500-MB. CHARTS

Very cold air was also found at the 500-mb. level just behind a pronounced trough and, of course, the air was also extremely dry. In these cases the cold, dry air was so far from the location of tornado occurrence as to preclude the possibility of its being directly associated although it was undoubtedly a factor in influencing the flow pattern prior to tornado development. In general, contour and isotherm patterns at this level were very similar to those found at the 700-mb. level but it was noted that no tornado cases were found in which the contours indicated an anticyclonic flow over Georgia some 8 to 20 hours prior to tornado development.

SUMMARY OF SYNOPTIC FEATURES

This study of soundings and of the various synoptic features revealed the following phenomena as being associated with tornadoes in Georgia:

1. Maritime tropical air at the surface, over a broad area, and with either cP or mP air to the west of a surface Low or front.
2. High moisture values to at least 5,000 feet. Inversions or isothermal layers may or may not be present and stability appeared to be unimportant.
3. Warm and moist air upstream at the 850-mb. level.
4. The trough line of a pronounced and moving 700-mb. trough, or Low center, somewhere between Amarillo, Tex., and Memphis, Tenn. This trough or Low must have developed over the Plains States or have moved in from the Northwestern States.
5. Cyclonic circulation at the 700- and 500-mb. levels over Georgia.

AN OBJECTIVE FORECAST AID

The results of this generalized study are difficult to evaluate because most of the similar situations which did not produce tornadoes have been ignored. Thus, in actual use, many more "threat" situations would arise than tornado cases and such generalized rules cannot, in general, accurately indicate the relative weight to be applied to the various rules so that too many cases are left open to question. It seemed desirable, therefore, to utilize the results of this study through specific definitions and measurements and then combine them into an objective forecast aid.

The stratification method used by Palmer [11, 12] and Schmidt [13], is not only a very useful tool for combining variables but it also produces an aid which demands an absolute minimum of the forecaster's time. This method is particularly well suited to a study of phenomena which occur as infrequently as do tornadoes in Georgia. We know from climatological data that tornadoes occur on only about 2 percent of all days during these months so it would be undesirable to develop a complicated procedure which must be followed on each day. Instead, using Palmer's method, one or two simple rules can be formulated so that most cases can be quickly and easily dismissed as "no-problem" cases.

Using the preceding phase of the study as a guide, rules were formulated to eliminate most of the no-tornado cases and, at the same time, to retain all of the tornado situations. Greater accuracy, in terms of percentage correct, could have been achieved through the elimination of a considerable number of no-tornado cases at the expense of a few tornado cases but it is believed that this would appreciably restrict the usefulness of this work. Indeed, the highest percentage correct most likely can be attained through a straight "no-tornado" forecast. These rules, along with a brief explanation of the purpose of some of them, are listed approximately in their order of importance in eliminating no-tornado cases.

Tornadoes in Georgia, during this period of study, occurred only when *all* of the following criteria were met:

1. 700-mb. height differences of 80 feet or more, Hatteras, N. C., *minus* Little Rock, Ark., *and* 110 feet or more, Las Vegas, Nev., minus Oklahoma City, Okla. This rule is intended to determine the existence or nonexistence of a trough located between Chattanooga, Tenn., and Albuquerque, N. Mex. (This criterion eliminated 479 cases of the 842 forecast periods studied.)
2. A surface dew point at either New Orleans, La., or Dothan, Ala., of 60° F. or higher during January, February, and March or 63° F. or higher during April. These dew points are commonly used in this area to define surface mT air. (This criterion eliminated 168 of the remaining 363 cases.)
3. A 700-mb. trough line (associated with a Low or trough at 35° N.) east of Amarillo, Tex., and west of Sault Ste. Marie, Mich. Winds that were north of west or contours indicating such a wind were used to determine that a trough was definitely east of these stations.
4. A latitude value, L_{500}, greater than 20° which is found by following the 500-mb. contour upstream through Atlanta to its lowest latitude east of 100° W. This criterion eliminated many situations in which a strong anticyclonic flow prevailed over Georgia at this level. There are infrequent situations in which the contour through Atlanta does not extend below 20° N., due to a closed anticyclonic circulation and a latitude value of 20° N. was arbitrarily assigned in these cases.
5. A 700-mb. temperature at Atlanta of −1.0° C. or warmer.
6. Appropriate parameters selected for any given situation and entered on figures 6, 7, 8, and 9 lo-

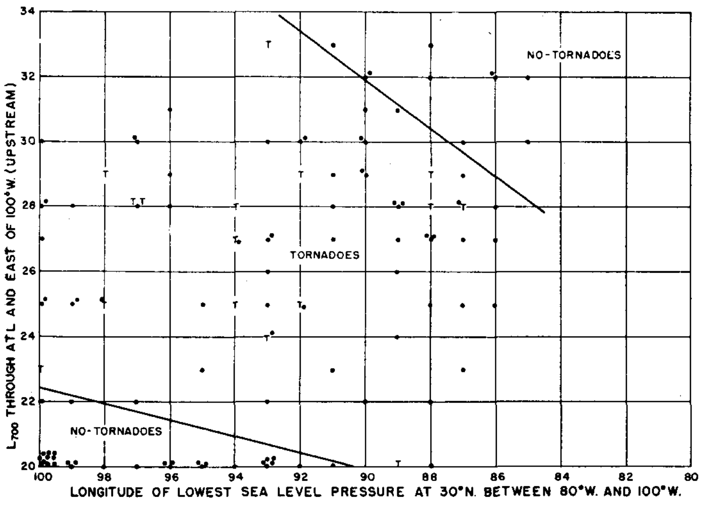

FIGURE 6.—Diagram showing the relation between the lowest latitude value, L_{700}, of the 700-mb. contour upstream from Atlanta (ATL) east of 100° W., and the longitude of the lowest sea level pressure along the 30th parallel between 80° and 100° W. for all cases not eliminated by any one of the 5 criteria (see p. 294). Prepared from 28 months of original data. "T" represents tornado periods and dot represents no-tornado periods.

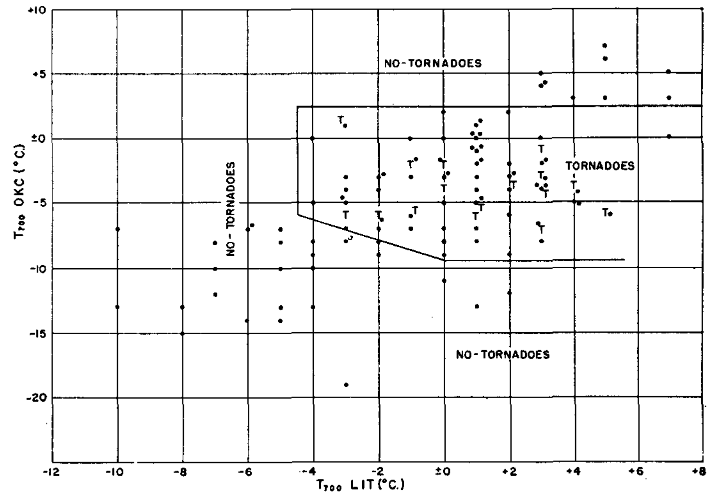

FIGURE 8.—Diagram showing the relation between the 700-mb. temperatures T_{700} at Oklahoma City, Okla. (OKC), and Little Rock, Ark. (LIT), for those same cases shown in figure 6.

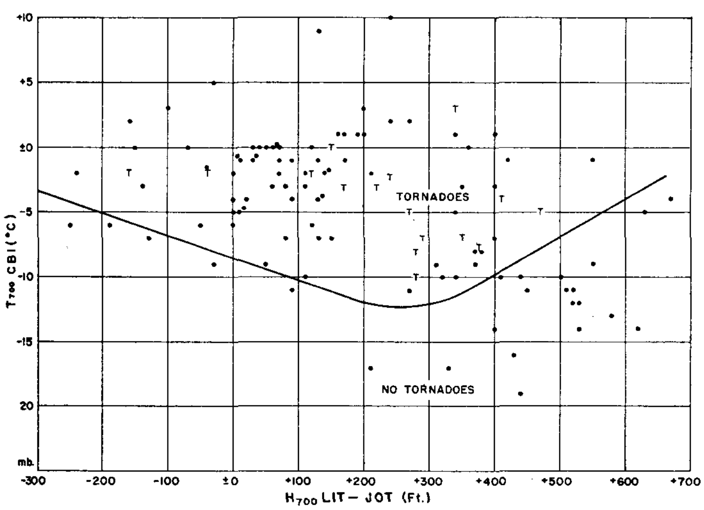

FIGURE 7.—Diagram showing the relation between the 700-mb. temperature, T_{700}, at Columbia, Mo. (CBI) and the 700-mb. height difference, H_{700}, Little Rock, Ark. (LIT) minus Joliet, Ill. (JOT) for those same cases shown in figure 6.

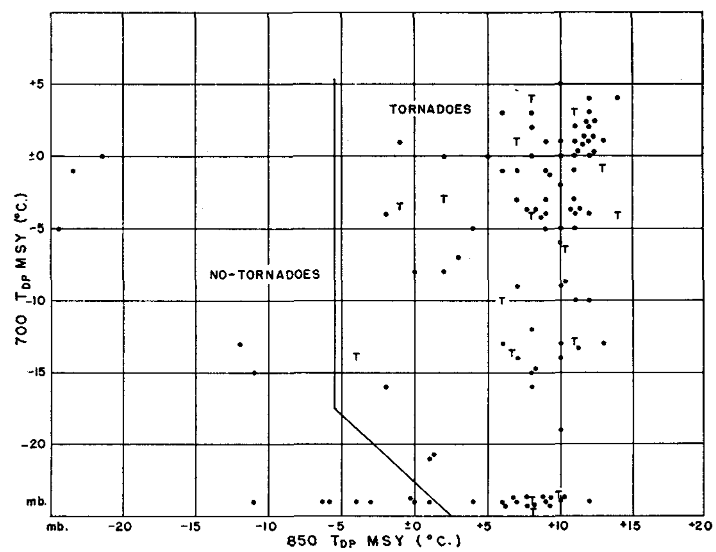

FIGURE 9.—Diagram showing the relation between dew point values (T_{DP}) at New Orleans, La. (MSY) at the 850- and 700-mb. levels for those same cases shown in figure 6.

cated the case in question within the "tornado area" of all four of these charts.

In figure 6, the longitude of the lowest sea level pressure along the 30th parallel, between 80° and 100° W., was usually found to be coincident with the position of a cold front at this latitude. L_{700} was determined by following the 700-mb. contour upstream from Atlanta to the lowest latitude value east of 100° W. As in the case of L_{500}, if there was a closed High so that the contour did not extend below 20° N. a latitude value of 20° was arbitrarily assigned. This diagram was intended to eliminate some of those cases of (1) small L_{700} values (anticyclonic circulation or a deep trough well west of Georgia) with sea level Lows or troughs which were also a considerable distance west of Georgia, and (2) those cases with large L_{700} values (troughs of small amplitude or troughs that have nearly reached Georgia) with sea level Lows or troughs that are already too far east to constitute a threat.

Figure 7 is intended to eliminate many cases of strong westerly flow in smooth troughs in which important convergence is lacking. One form of convergence at this level results from sharp troughs with marked changes in wind direction within short distances. On the other hand, the smooth trough with strong westerly winds is not often associated with rain or thunderstorms in this area. In these cases, the cold air usually moves in from the northwest and reaches Columbia, Mo., before reaching Oklahoma City. The 700-mb temperature at Columbia is used as a measure of this cold air. The 700-mb. height difference, Little Rock, Ark., minus Joliet, Ill., is intended

WORK SHEET FOR GEORGIA TORNADO STUDY

Month ____________ Year ________

Date	Time	H_{700}		Sfc T_{DP} MSY or DHN	700-mb trough line		L_{500} ATL	T_{700} ATL	Fig. 6		• Fig. 7		Fig. 8		Fig. 9		Forecast	Observed
		HAT-LIT 80 or more	LAS-OKC 110 or more	>59° F (>62°Apr)	East of AMA	West of SSM	>20°	-1.0° C or warmer	L_{700} ATL	Long. of lowest sfc P at 30°N	T_{700} CBI	H_{700} LIT-JOT	T_{700} OKC	T_{700} LIT	T_{DP} 850	T_{DP} MSY 700		

FIGURE 10.—Illustration of a work sheet for this study which is used at the Atlanta District Forecast office to facilitate the compilation of data in actual forecasting.

as a measure of the strength of the westerlies at 700 mb. and, indirectly, a measure of convergence at this level.

Figure 8 simply delineates the 700-mb. temperature range at Oklahoma City and/or Little Rock which was subsequently followed by tornadoes. For example, very low temperatures at Oklahoma City and/or Little Rock seem to preclude tornado development. Also, very warm temperatures at Oklahoma City were not associated with subsequent tornado development in Georgia.

Figure 9 illustrates the importance of high moisture values at both the 850-mb. and 700-mb. levels at New Orleans. Tornadoes in both of the cases in which the 850-mb. dew point was less than 0° C. occurred very early in the forecast period and followed a period during which tornadoes were reported. It is interesting to note here that dry air at the 700mb. level is apparently not necessary for tornado development in the Southeast.

Since considerable use was made of temperature data it might be expected that better results would be found in using departures from normal or otherwise taking some account of the seasonal variation when so many different months were used. Some "normal" values were computed for the four months of original data but it was found that consideration of the departure from normal resulted in only slight improvement. It was therefore felt that additional confusion involved in using these results would not warrant their use. In addition, it will be very easy for the forecaster to give some consideration to this seasonal effect when he is actually applying the method.

All of the above criteria were met 37 times during this period of study and tornadoes were reported during 16 of these 12-hour periods. No tornadoes were reported which did not meet *all* of these criteria. Of the 21 periods for which tornadoes were "forecast" but were not reported, rain was observed in all cases; thunderstorms were reported in 18 cases; and a cold front preceded by an instability line was noted in most of these situations. There were, of course, many other situations in which thunderstorms occurred but it is encouraging to note that when this method is in error, it is a matter of degree. Further study of both the tornado cases and "error" cases suggests that the difference between tornadoes and thunderstorms in this area and season is often fortuitous.

In actual use at the District Forecast Office in Atlanta, the compilation of data is somewhat simplified through the use of the work sheet illustrated in figure 10. It is seldom necessary for the forecaster to check through all of these data since failure to meet any *one* of these criteria immediately eliminates a situation from further consideration. It was not possible to make a reliable analysis of probabilities on any of the scatter diagrams (figs. 6, 7, 8, and 9) nor did there seem to be any obvious relationship between the various parameters and the number of tornadoes reported with any given storm. In drawing the lines which separated tornado cases from no-tornado cases on these scatter diagrams and in developing the first 5 criteria, some allowance was made for values beyond those actually found in the 16 tornado periods studied. For example, tornadoes followed only those cases in which the height difference, Hatteras minus Little Rock, was 100 feet or more but in compiling data, values of 80 feet or more were used. In general, data from a situation with only one or two tornadoes fell closer to the lines of separation between tornado and no-tornado cases than the data for more severe storms. The same is also true of data for tornado cases occurring in the early part of a forecast period following a period in which tornadoes occurred. However, data appear to be too limited to justify such a conclusion at this time so that the results of this study, in themselves, do not permit an estimate of the severity of these storms.

TESTS

The number of tornado occurrences in Georgia is so small that it seemed best to utilize all of the available data in formulating a method and then resort to data from adjacent areas and months for testing. These test data are not strictly comparable to the dependent data so that the tests should be expected to show somewhat inferior results than would be true with comparable data. The frequency of tornado occurrences increases westward through Georgia and Alabama but the frequency difference between Georgia, particularly west Georgia, and that portion of Alabama which lies east of a north-south line through Birmingham is probably small. There will, of course, be some time difference due to the distance involved and perhaps some climatological or meteorological differences. Tests were made with the following data: (1) Constant height data from 1942 through 1945 for both Georgia and eastern Alabama; (2) November and December constant pressure data for both Georgia and eastern Alabama from 1946 through 1952; (3) constant pressure data for eastern Alabama from 1946 through 1952 for January through April; and (4) very limited testing on Georgia tornadoes only, made with the analyzed Northern Hemisphere maps from 1934 through 1939.

The criteria were tested on all tornado cases which were reported in eastern Alabama during January through April from 1946 through 1952. Ten cases occurred but six of these preceded tornadoes in Georgia which were used as dependent data. Three of the remaining four tornado cases were not forecast by this method but two of these errors were due to a time lag and therefore not considered to be serious. The third error was due to a number of criteria not being met so that case was decidedly different from those examined in Georgia.

There were 12 tornado cases in Georgia, eastern Alabama, or both from 1942 through 1945 and constant height data were available for those cases. It was not possible to make an exact check of these criteria because of data differences and deficiencies, but all of the criteria appeared to have been met in 10 cases. Both errors were due to the occurrence of tornadoes when several of the criteria were not satisfied.

The climatology for the months of November and December, particularly November, is somewhat different than for the months used in this study. However, data for tornado occurrences in Georgia and eastern Alabama during the months of November and December for the years 1946 through 1952 were compiled and these criteria tested on those cases. Eight tornado periods were reported during this period and all criteria were met in seven of them. The case that was missed involved three tornadoes in north central Alabama that occurred very late in the forecast period. In the following period, all criteria were met with the exception of the 700-mb. temperature at Oklahoma City which was 2° C. too warm. The seasonal effect is much larger than this and the tornadoes occurred quite a distance from Georgia so this "error" is not considered to be a serious one.

As an additional check upon the validity of these rules, all tornado cases in Georgia were checked against the surface, APOB, and winds aloft charts that were available. This period covered the years 1934 through 1939 and included 21 cases. This test was, of course, only an approximation because of very limited data, particularly temperatures, but it did permit some check of the first three criteria. Also, the fourth criterion was checked by using the analysis at the 3-km. level. The criteria involving the pressure distribution appeared to have been clearly met in 18 of these cases; 1 case was questionable, and 2 other cases were definitely in error. Although surface dew points were not available in all of these cases, mT air at the surface was apparently always present. These tests on data from eastern Alabama and over these many years indicate that not all tornadoes in this area can be correctly forecast by this method but it was noted that almost all of the errors were connected with the occurrence of single tornadoes. In other words, the situations involving two or more tornadoes seemed to fit the pattern defined by the criteria. No check was made of the number of tornadoes that would have been "forecast" from these rules when none were reported but it seems reasonable to expect that the number would not vary appreciably from that found in the 28 months of original data.

This objective aid was available to forecasters during the 1953 season which, from the standpoint of number of tornadoes reported, was one of the worst on record. During this period, the objective aid "forecast" tornadoes for Georgia for 11 different 12-hour periods and tornadoes were reported in 4 of these periods. In 3 of the remaining 7 cases, tornadoes were reported in eastern Alabama. One tornado period in Georgia occurred (3 tornadoes) which was not forecast by this method, and one small tornado which destroyed a tool shed in eastern Alabama was not anticipated by this method. Considering the difficulty of predicting any record-breaking weather phenomenon, either subjectively or objectively, these results are not too disappointing.

CONCLUSIONS

It is not expected that this study will solve the tornado forecasting problem in Georgia but it is hoped that the climatological and statistical data, along with the rules which were devised, will be of material aid to the forecasters in this area. In addition, the data will provide a much-needed confidence factor in a large percentage of the problem situations. Strict adherence to these rules can be expected to result in about 2½ forecasts of tornadoes for every one that occurs (based upon 28 months of original data plus 4 months of independent data) and some will be missed entirely. While this number of "alerts" is somewhat large, it has been estimated that for every tornado reported in this area, there is another or perhaps even two tornadoes that have occurred in sparsely populated areas and consequently were never reported. It is hoped that experience in the application of these rules in actual forecasting will provide some basis for their refinement and that thereby a considerable improvement in the accuracy of severe storm warnings in this area may be achieved.

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